

DIFFERENT ZOOPLANKTON COMMUNITIES IN CONFLUENT WATERS: COMPARISONS BETWEEN THREE MARINE BAYS IN VICTORIA, AUSTRALIA

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Zooplankton was collected from two sites in Swan Bay (adjacent to, and confluent with, Port Phillip Bay), Victoria, from February 1984 to January 1985. The copepod *Acartia tranterii* Bradford was numerically dominant throughout the year. The zooplankton assemblage in Swan Bay was more similar to that of the remote Westernport Bay than to the adjacent Port Phillip Bay. It is suggested that the presence of seagrass in Swan Bay and Westernport Bay had a strong, although indirect, influence on the nature of the zooplankton community by adding a significant amount of detritus to these systems and by providing habitat for small planktivorous fish.

DIFFERENCES in the zooplankton fauna of two closely situated bays, Port Phillip Bay and Westernport Bay (Fig. 1), have been attributed to their different physical and biological characteristics such as depth profiles, predator abundance, concentration of suspended matter and degree of tidal exchange with Bass Strait (Kimmerer & McKinnon 1985). For example, Westernport Bay is smaller and shallower and supports a very extensive eelgrass community (Robertson & Howard 1978), whereas Port Phillip Bay consists of a large, relatively deep basin with seagrass restricted to the shallow margin (Bulthuis et al. 1992). A consequence of this is that Westernport Bay may support a largely detritus-based ecosystem which has its energetic origins in the seagrass beds while the food web of Port Phillip Bay is more likely to be phytoplankton-based.

Swan Bay is located at the southern end of Port Phillip Bay (38°14'S, 144°40'E). It is a shallow, semi-enclosed body of water that covers an area of approximately 19 km² (Fig. 1). The maximum depth of Swan Bay is approximately 2.5 m. Two channels, one north and one south of Swan Island, provide limited tidal exchange with Port Phillip Bay. Intertidal mudbanks are common throughout the bay, and there is extensive coverage by seagrass; most commonly *Heterozostera tasmanica* (Denning et al. 1986).

Swan Bay is partially independent of, and different in character to, Port Phillip Bay, and so allows an extension to the comparative studies of Port Phillip Bay, Westernport Bay and Bass Strait undertaken previously (Kimmerer & McKinnon 1985). Although Swan Bay has direct tidal

exchange with Port Phillip Bay, it exhibits many characteristics closer to those of Westernport Bay, in particular, the presence of extensive seagrass beds. Thus, the area provides an opportunity to examine the factors that control a zooplankton assemblage. Does the species pool available for recruitment from Port Phillip Bay entirely dictate which organisms are able to live in Swan Bay, or is the assemblage determined by some combination of local biotic and abiotic factors?

The main objective of this study was to examine the zooplankton assemblage of Swan Bay and compare it to those of both Port Phillip Bay and Westernport Bay. The zooplankton in Swan Bay was sampled over a full year. The data were used to construct a species abundance curve that was compared to those from Port Phillip Bay, Westernport Bay and Bass Strait. Inferences were then made about the possible factors governing the species assemblage in Swan Bay.

MATERIALS AND METHODS

Zooplankton in Swan Bay was sampled monthly from February 1984 to January 1985 from two sites, one nearshore and one offshore (Fig. 1). At each site, four replicate samples were collected using a Clarke-Bumpus plankton sampler (mesh size 167 µm) that was towed for five minutes at a depth of one metre. Samples were collected during daylight hours at high tide. All samples were immediately preserved with 5% formaldehyde. In the laboratory, samples were fractionated so that between 500 and 800 individuals were counted for

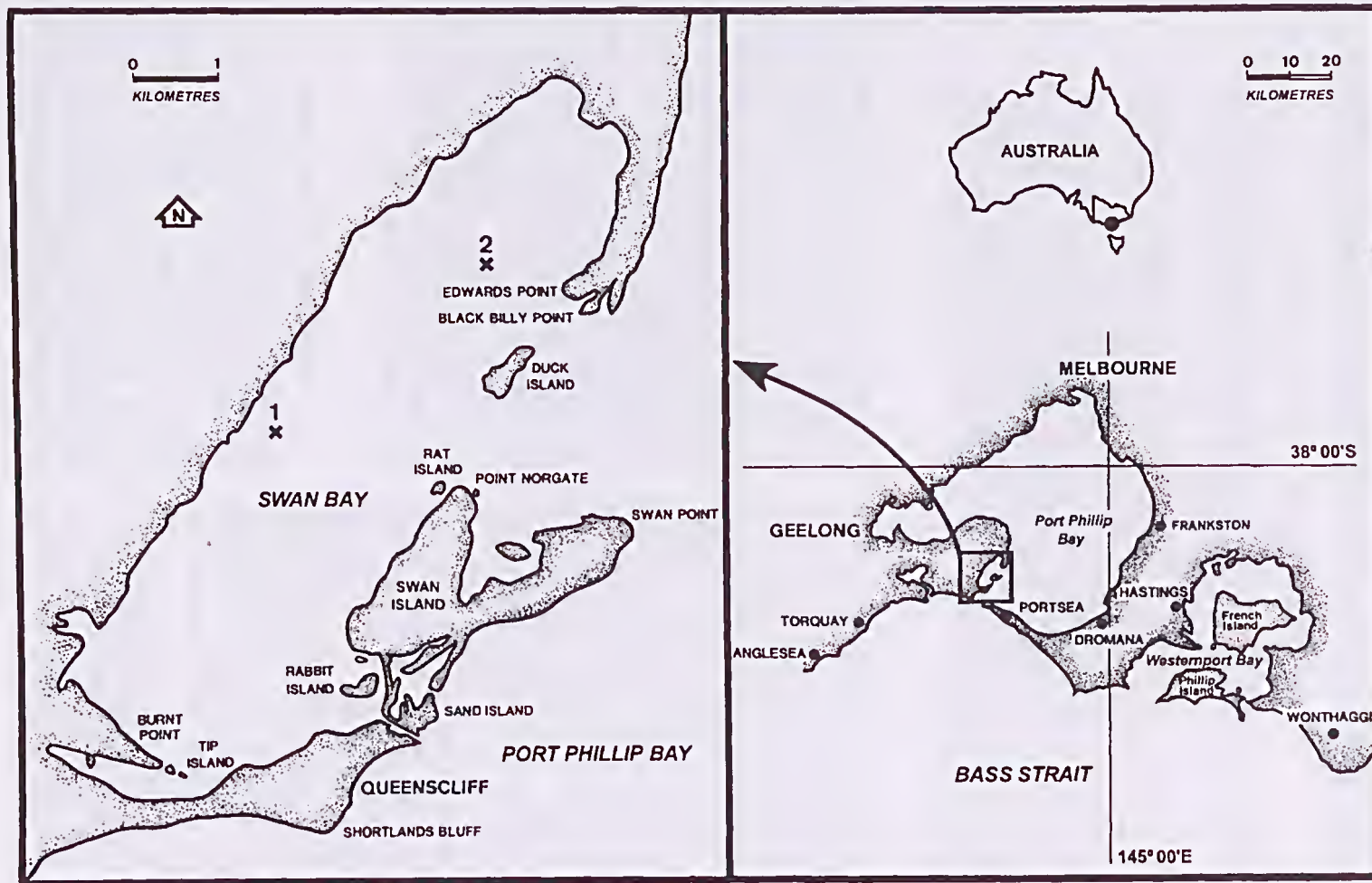


Fig. 1. Map showing location of Port Phillip Bay, Westernport Bay and Swan Bay. The location of the two sampling stations employed in Swan Bay is indicated by numerals 1 and 2.

each field replicate. Staining with rose bengal (Hellawell 1978) facilitated sorting when a large quantity of detritus was present. Zooplankton were identified to the lowest possible taxon. Geometric mean abundances were calculated using the transformed $\log(x+1)$ values (Sokal & Rohlf 1981). Student's *t*-test was used to test for differences between the mean zooplankton densities at each station.

On each sampling date, surface and bottom temperatures were measured using a mercury-in-glass thermometer. Water depth was measured with a graduated lead-line. Replicate mid-water samples (Van Dorn sampler) were collected for the determination of salinity using the conductivity ratio method (UNESCO 1966).

Phytoplankton samples were collected from mid-water depth using a Van Dorn sampler. Chlorophyll-*a* was extracted from the samples using the method of Nusch (1980). Absorbance was measured at 665 and 705 nm with a Varian-Techtron Spectrophotometer. Correction for phaeophytins was made by acidifying the extract with 3 μ L 2M HCl/mL, and re-measuring the absorbance after 15 minutes. From May 1984 replicate mid-water samples were collected to measure total suspended matter in the water column. Samples were filtered onto preweighed Oxoid membrane filters (0.45 μ m), dried at 60°C for four hours, cooled in a desiccator, and weighed to constant weight.

In order to characterise the distribution of species abundance in the zooplankton community of Swan Bay, a curve was constructed for the twelve most commonly occurring species; defined as those that were found to occur in more than one third of the samples. The $\log(x+1)$ abundance of each species was plotted against its rank, from the most frequently occurring species to the least. Comparisons were made to similar curves that had been developed for Port Phillip Bay, Westernport Bay and Bass Strait zooplankton communities (Kimmerer & McKinnon 1985).

RESULTS

Water depth ranged between 1.1 and 1.8 m at Station 1 and 1.8 and 2.5 m at Station 2. Surface seawater temperatures ranged between 9.8°C in June and 18.5°C in February. As expected for a shallow water column, thermal stratification was negligible; the maximum difference between surface and bottom temperatures was 0.3°C. Salinity varied between 33.1‰ in March and 39.6‰ in June.

Chlorophyll-*a* concentration ranged between 3.5 μ g L⁻¹ in February and 0.5 μ g L⁻¹ in April at Station 1 (mean=1.3 μ g L⁻¹) and between 2.2 μ g L⁻¹ in March and 0.3 μ g L⁻¹ in August (mean=0.9 μ g L⁻¹) at Station 2. Total suspended matter in the water column varied from 1.5 to 116.7 mg L⁻¹ at Station 1 and from 1.7 to 66.3 mg L⁻¹ at Station 2. There was no consistent seasonal trend; the amount of suspended matter appeared to be a function of prevailing weather conditions. Total suspended matter reached a maximum concentration in August when wind speeds reached at least 35 knots.

Geometric mean abundance of zooplankton reached a maximum (11 200 individuals m⁻³) in February and a minimum (570 individuals m⁻³) in July at Station 1 (Fig. 2). Mean abundance at Station 2 ranged from 1100 individuals m⁻³ in February to 220 individuals m⁻³ in June (Fig. 2). Mean densities at Station 1 were significantly greater than those at Station 2 (Student's *t*-test; *t*=3.434; d.f.=21; *P*<0.01). The zooplankton assemblage was dominated by Crustacea, particularly calanoid copepods. Other taxa represented included Mollusca, Leptomedusae, Chelicerata, and Polychaeta. In general, a greater number of taxa was collected at Station 2 but numerical abundances were usually considerably lower.

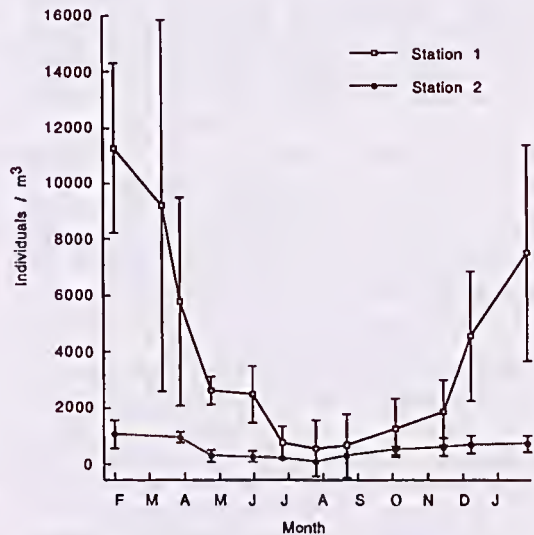


Fig. 2. Geometric mean zooplankton abundance at two stations in Swan Bay over the period February 1984 to January 1985.

	Station 1		Station 2	
	Mean	Range	Mean	Range
COPEPODA				
<i>Acartia tranteri</i>	3686	(509–11140)	611	(185–1668)
<i>Paracalanus indicus</i>	3	(1–19)	3	(1–11)
<i>Pseudodiaptomus cornutus</i>	47	(16–184)	9	(1–37)
Other Calanoida			1	(1–3)
<i>Oithona rigida</i>	48	(1–425)	36	(1–201)
<i>Oithona</i> sp.	27	(10–232)	28	(6–137)
<i>Kelleria corioensis</i>	7	(2–34)	5	(2–31)
<i>Metis</i> sp.	15	(6–68)	12	(1–64)
<i>Euterpina acutifrons</i>	2	(1–11)	2	(1–12)
Other Harpacticoida	7	(1–85)	1	(1–4)
OTHER TAXA				
Amphipoda	1	(1–9)	2	(1–4)
Isopoda	2	(4–19)	3	(1–15)
Decapoda	1	(2–3)	35	(1–10)
Mollusca	2	(1–16)	2	(1–8)
Polychaeta	1	(1–2)	4	(1–28)
Leptomedusae			7	(1–29)
Acariniidae	1	(1–2)		
Pisces	5	(2–50)	2	(1–8)

Table 1. Mean abundance (no. m^{-3}) of major taxa collected at each station over sampling period from February 1984 to January 1985. Range of abundances (minimum to maximum) shown in parentheses.

Acartia tranteri Bradford was numerically dominant throughout the sampling period at both stations, representing on average 82% of the total zooplankton numbers (Table 1). *Paracalanus indicus* Wolfenden, the most common calanoid copepod recorded from Port Phillip Bay (Arnott 1974b; Kimmerer & McKinnon 1985) was recorded in low numbers, the maximum abundance being $23 m^{-3}$ in March. The only other regularly recorded calanoid copepod was *Pseudodiaptomus cornutus* Nicholls. This is a benthopelagic species that migrates vertically (Fancett & Kimmerer 1985), and therefore was likely to be under-represented in daylight samples from Swan Bay.

The most abundant cyclopoid copepod, *Oithona rigida* Giesbrecht, was recorded most frequently from Station 2. However, when it was present, abundances were higher at Station 1. Low numbers of *Kelleria corioensis* Arnott & McKinnon and *Oithona* sp. were also recorded. *Euterpina acutifrons* Dana, a planktonic harpacticoid copepod, was collected throughout the sampling period, although generally in low numbers. Other harpacticoids occurred rarely and most likely

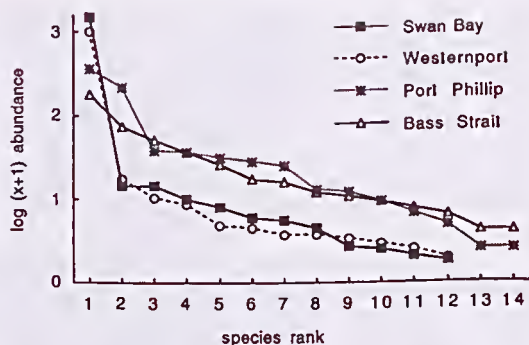


Fig. 3. Species abundance curves for Swan Bay, Westernport and Port Phillip Bays, and Bass Strait. Data for the last three localities from Kimmerer and McKinnon (1985).

represented benthic 'strays'. Amphipods, isopods and decapods were recorded from the stations occasionally and usually as the larval stages of benthic species. Other meroplanktonic organisms collected included trochophore larvae of polychaetes, mollusc larvac, pycnogonid larva (single specimen), acariniids and larval fish. The Leptomedusae, *Clytia hemispherica* and *Obelia* sp., were commonly collected from both stations.

Figure 3 shows log abundance plotted against species rank for Swan Bay, Westernport Bay, Port Phillip Bay and Bass Strait. Swan Bay was most similar to Westernport Bay in that the zooplankton assemblages were dominated by one species: *Acartia tranteri* in both cases. In terms of abundance, other species contributed relatively little to the total. In contrast, Swan Bay was dissimilar to Port Phillip Bay, which closely approximated Bass Strait in that there was not one predominant species but at least two that were contributing substantially to the total abundance. The two numerically abundant species in Port Phillip Bay were *A. tranteri* and *Paracalanus indicus* (Kimmerer & McKinnon 1985).

DISCUSSION

Comparison of the species abundance curves in Fig. 3 suggests abundance and distribution patterns of the Swan Bay zooplankton assemblage were much closer to those of Westernport Bay than to those of Port Phillip Bay, even though Swan Bay is hydraulically continuous with the latter. Unlike Port Phillip Bay, Swan Bay was strongly dominated by one species, *Acartia tranteri*. More-

over, *Paracalanus indicus*, a common species in Port Phillip Bay, was present only in low numbers in Swan Bay and other taxa which were all common in Port Phillip Bay, such as several species of cladocerans and larvaceans, were completely lacking in Swan Bay. Therefore it can be concluded that the broad hydraulic connection with Port Phillip Bay was only a minor factor affecting the species assemblage of Swan Bay.

Although the shallowness of Swan Bay suggests it was likely to experience wider short-term temperature fluctuations, the seawater temperatures during 1984 were not substantially different from those in the other two bays (Kimmerer & McKinnon 1985). Further, salinity values were similar for the three water bodies even though Swan Bay did become hypersaline during the winter (maximum salinity=39.6‰; c.f. 37.1‰ for Port Phillip Bay and 37.8‰ for Westernport Bay). Kimmerer & McKinnon (1985) concluded that temperature and salinity did not have a significant effect on the taxonomic differences they observed, and this study supports that conclusion.

High detrital levels in the water column may explain some of the differences observed. Large quantities of detritus found in Swan Bay (this study) and Westernport Bay (Arnott 1974a, 1974b) result from extensive seagrass coverage. Of those organisms commonly found in Port Phillip Bay but not in Swan Bay, for example *Paracalanus indicus*, some cladoceran species, and larvaceans, most are suspension feeders. These animals must either consume detritus, a comparatively poor food source, or actively take measures to reject it (Heinle et al. 1977). While some planktonic organisms are able to do this (e.g. Richman et al. 1977; Koehl & Strickler 1981), others, such as larvaceans, are unselective and so face difficulties with clogging of their incurrent filters (Allredge 1976). In contrast, *Acartia* species are often numerically dominant in bays with high particulate content (Trinast 1975; Paffenhofer & Stearns 1988), and therefore must be able to tolerate detritus. Thus the high levels of detritus in Swan Bay might influence which species can successfully colonise the bay.

Phytoplankton abundance is partially limited by water temperatures and, in turn, limits zooplankton abundance. As chlorophyll-*a* concentrations (a measure of phytoplankton biomass) were consistently low in all three bays under consideration (Kimmerer & McKinnon 1985) when compared to values from temperate bays elsewhere (e.g. Durbin & Durbin 1981) it is unlikely that this factor alone was responsible for the observed differences.

Kimmerer & McKinnon (1987) showed that predation by small planktivorous fish on *P. indicus* was approximately twice that of predation on *A. tranteri*. They suggested that seagrass beds in shallow waters, such as those found in Westernport Bay, provide habitat for high numbers of small planktivores that are primarily visually oriented predators. In their study Kimmerer & McKinnon (1987) showed that *Acartia tranteri* was less visible in the water column and also had a greater ability to avoid capture than *P. indicus*. Their conclusion was that predation by fish had an important role in structuring the zooplankton assemblage of Westernport Bay. It is possible that such a mechanism is also operating in Swan Bay. The shallow waters and extensive seagrass beds do provide habitat for large numbers of small planktivorous fish (R. Jessop, personal communication, 1984). However, until predation pressure in Swan Bay can be quantified, its role in structuring the zooplankton assemblage will only be conjecture.

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